Nonlinear Dynamics and the Reactive Synthesis of InN

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ABSTRACT

While design and characterization are crucial components of the development of new materials, synthesis is an equally important step. Synthesis of new materials for energy related applications typically proceeds through a complicated set of metastable states. Interactions between these states can lead to surprising results. In this talk we present results from x-ray scattering studies of the organometallic vapor phase epitaxial growth of InN on GaN (0001) surfaces. InN (and the related InGaN alloys) have great potential for applications in solid state lighting and electronic devices. Unfortunately, InN at typical growth conditions of 600-700°C and 1 bar pressure is unstable, and requires an equivalent nitrogen activity of 1000 bar of N_2 to prevent decomposition. Thus, growth of InN relies on the production of active nitrogen from the decomposition of ammonia, resulting in a growth process that is poorly understood.

We have used *in situ* synchrotron x-ray diffraction and fluorescence measurements, coupled with visible light scattering, to gain insight into the underlying processes. During these studies, we discovered self-sustaining oscillations in x-ray signals during growth under constant input flows. First, islands of crystalline InN nucleate and grow. The InN islands then spontaneously and collectively transform into elemental In liquid droplets. The In droplets then evaporate to a point where they convert back to InN. The InN crystals grow until they transform to liquid In, and the cycle begins again. Imaging visible light scattering during growth reveals moving boundaries with linear, circular and spiral geometries between areas covered with liquid In and with InN.

This behavior is qualitatively explained by a model in which the effective nitrogen activity produced during catalytic decomposition of NH_3 at the substrate depends on the exposed surface areas of GaN, InN and In. This phenomenon not only opens up a new class of excitable media involving transformations between vapor and bulk condensed phases for fundamental studies of nonlinear dynamics, but also provides insight into the nature of the chemical mechanisms involved in synthesis of metastable materials such as InN.

This work, including use of the Advanced Photon Source and Center for Nanoscale Materials, is supported by U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract DE-AC02-06CH11357.